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Added value of combining multiple optical and acoustic instruments when characterizing fine-grained estuarine suspensions

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ADDED VALUE OF COMBINING MULTIPLE OPTICAL AND ACOUSTIC INSTRUMENTS WHEN CHARACTERIZING FINE-GRAINED ESTUARINE SUSPENSIONS

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VERIFICATION

ABSTRACT

Various optical and acoustic instruments have specific advantages and limitations for characterizing suspensions, and when used together more information can be obtained than with one instrument alone. The LISST 100X, for example, is a powerful tool for estimating particle size distribution, but because of the inversion method used to determine the size distribution, it is difficult to distinguish two populations that peak close to one another, especially among large grain sizes. In the York River estuary, VA, additional information obtained through the deployment of a RIFScam camera system and an ADV along with the LISST 100X allowed differentiation between populations of particles in the water column and flow in suspension close to the bottom and how the particles varied over a tidal cycle. A second example of instrument pairing providing additional information was the use of a PIV video imaging system in the York River to verify the conditions under which use of the ADV Reynolds flux method was valid for estimating settling velocity of suspended particle populations.

MOTIVATION

Identify the contribution of multiple particle types to the suspended distribution and thus to the effective settling velocity (Ws as measured by the ADV).

INSTRUMENTS to measure Settling Velocity (Ws) as measured by:

Acoustic Doppler Velocimeter (ADV)

Advantages:

- Non-invasive single-point velocity measurement
- Less susceptible to bio-fouling and can be used in higher concentration ranges than optical instruments
- Burst data used to estimate effective settling velocity (Ws), as well as flux, turbulence, stress, and concentration when calibrated

Disadvantages:

- Cannot track individual or groups of particles—only valid for effective (bulk) Ws
- Profiler must be stationary—profile motion interferes with velocity calculations

Particle Imaging Camera System (PICS)

Advantages:

- Individual measured particle size and settling velocity allows estimation of particle density
- PIV/PIV removes fluid velocity allowing for Ws estimates in situ (stationary profiler not necessary)
- 30 sec of video allows averaging for better estimate of size and Ws
- Can capture large particles

Disadvantages:

- Pixel size limits resolution of small particles
- Data processing is time intensive
- Cannot be used in high concentration regimes
- Currently not set up for autonomous deployment

RESULTS

- Reduction of sediment concentration (Figure 3B) by 50% resulted in less than 1% change in ADV-based estimates of Ws (using modified Reynolds flux equation).
- Modified Reynolds flux method (ADV) for estimating mean Ws was noisier than PIICS settling column observations (Figure 4B).
- PIICS observed mean settling velocities (0.5-1.0 mm/sec) were consistent with ADV-based effective estimates for cases with Ws = 0.5 mm/sec (0.5-1.0 mm/sec).
- PIICS observed mean settling velocities were not consistent with ADV-based effective estimates for cases with Ws > 2 mm/sec.
- For Ws > 20 mm/sec (0.1-0.2 < C < 0.4 C), ADV provides appropriate sediment flux balance for ADV Ws calculation (Figure 5).

CONCLUSIONS

- Using multiple instruments with various capabilities provides a more complete picture of the particle size distribution and their associated settling velocities.
- Both PIICS and ADV in study 1 do a reasonable job of describing the mean/effective Ws when Ws > 20 mm/sec. All observers suspected sediment suspension is insufficient to provide valid ADV flux estimates using the modified Reynolds flux method.
- ADVs, however, provide longer-term continuous estimates of Ws when it is impossible to deploy other instruments (for example during episodic events).
- PIICS overestimates the mean or effective Ws because it is limited by pixel resolution. ADVs are likely biased towards particles which are larger and deeper and thus produce stronger acoustic backscatter.

- Combination of the L.I.S.T., which is better at resolving smaller particles, and the R.I.F.S.c.m., which is better at resolving larger particles, does a reasonable job in describing the “total” distribution. However, neither of these instruments are capable of direct measurement of Ws.

- Addition of L.I.S.T.-SI to PIICS can help resolve contribution of the smaller particles particularly in the low stress periods.

CONCLUSION

METHOD--STUDY 1

6 Hour Study Period bracket Flood (Oct 6, 2012)

LISST00X – • 4 burst/study, 2 min/1 h (10 samples/record)
ADV – 2 min/1 h (10 burst)

PICS – 30 frames corresponding to each ADV/LISST burst.

RESULTS

- Reduction of sediment concentration (Figure 3B) by 50% resulted in less than 1% change in ADV-based estimates of Ws (using modified Reynolds flux equation).
- Modified Reynolds flux method (ADV) for estimating mean Ws was noisier than PIICS settling column observations (Figure 4B).
- PIICS observed mean settling velocities (0.5-1.0 mm/sec) were consistent with ADV-based effective estimates for cases with Ws = 0.5 mm/sec (0.5-1.0 mm/sec).
- PIICS observed mean settling velocities were not consistent with ADV-based effective estimates for cases with Ws > 2 mm/sec.
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Verifying the utility of acoustic Doppler current meter (ADCM) and laser Doppler velocimeter (LDV) data in coastal waters. Geosciences, 2013, 2012, 2. 15–20


Advantages:

- Good resolution of smaller particle sizes (21 of 32 logarithmically spaced size classes <100 µm)
- Simple deployment and data processing
- Can be deployed autonomously

Disadvantages:

- Highly susceptible to bio-fouling when deployed autonomously
- Poor resolution of large particles and limited range

METHOD--STUDY 2

25 Hour Study Period (July 28-29, 2009)

LISST00X – • 4 burst/study, 2 min/1 h (10 samples/record)
ADV – 2 min/1 h (10 burst)

PIICS – 30 frames/record, 1 min burst interval, 5 flash exposures @ 1 min intervals (light depth = 2mm)

RESULTS

Example Distributions

Low Stress Period (Figure 6 A-B)
- LISST D05 and DIS explain variance results (p > 0.15) suggest dominant floc size of ~10 µm
- LISST D05 and DIS suggest larger sized particles in suspension

Increasing stress period (Figure 6 C-D)
- Broader LISST distributions suggests multiple particle types in suspension
- LISST D05 and DIS suggest dominant particle size is ~100 µm

CONCLUSIONS

- Increased LISST volume concentration of comparable “pellet” size class
- Increased LISST volume concentration of comparable “floc” size class
- Increased ADV effective Ws
- Increased LISST volume concentration of comparable “floc” size class

PELLETS (~100 µm)
- Increased LISST volume concentration of comparable “floc” size class

RESILIENT PELLET
- Increased ADV effective Ws
- Increased LISST volume concentration of comparable “pellet” size class

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